WDM for Military Platforms Workshop
April 18-19, 2000

WDM Sensor Networks for Military Platforms

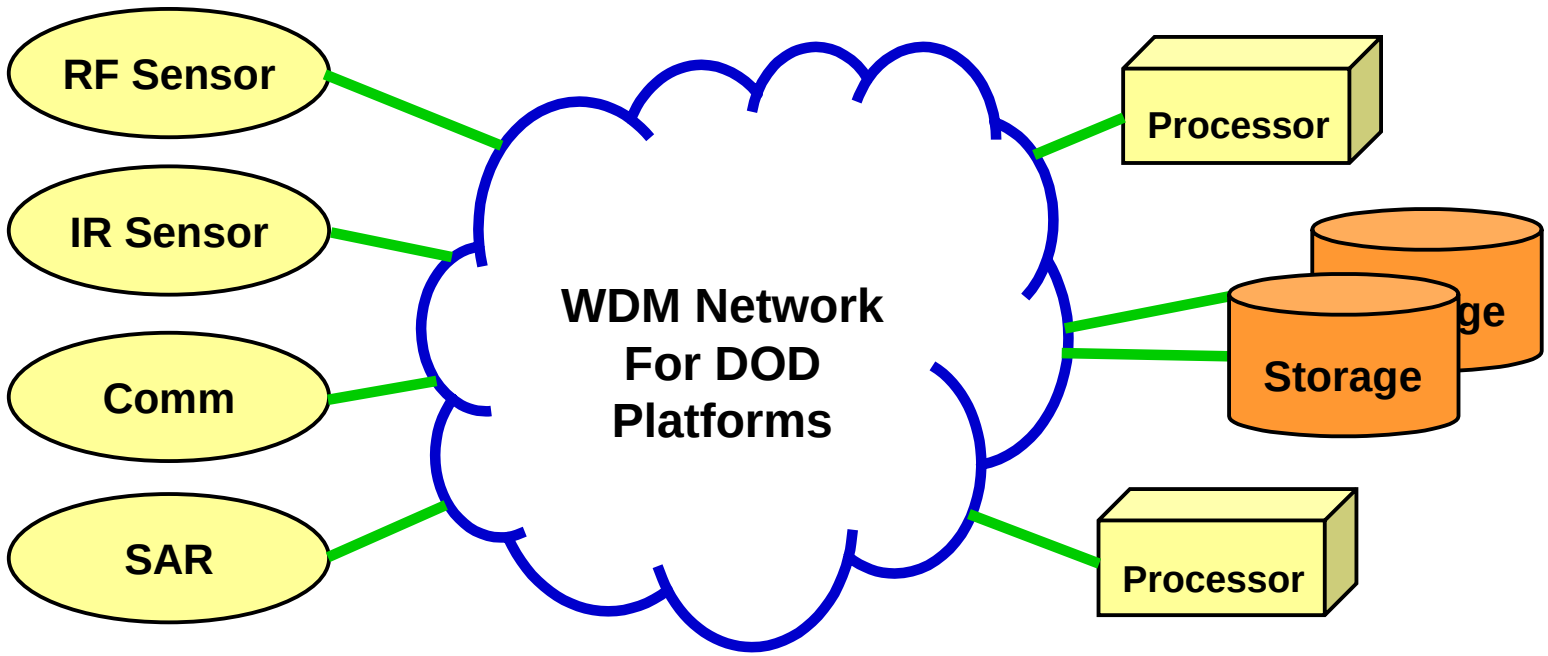
Ming C. Wu

UCLA

OUTLINE

- **The emerging Optical Transport Networking (OTN) for telecom**
- **WDM sensor networks**
- **New components required**
- **New functions enabled by the network**

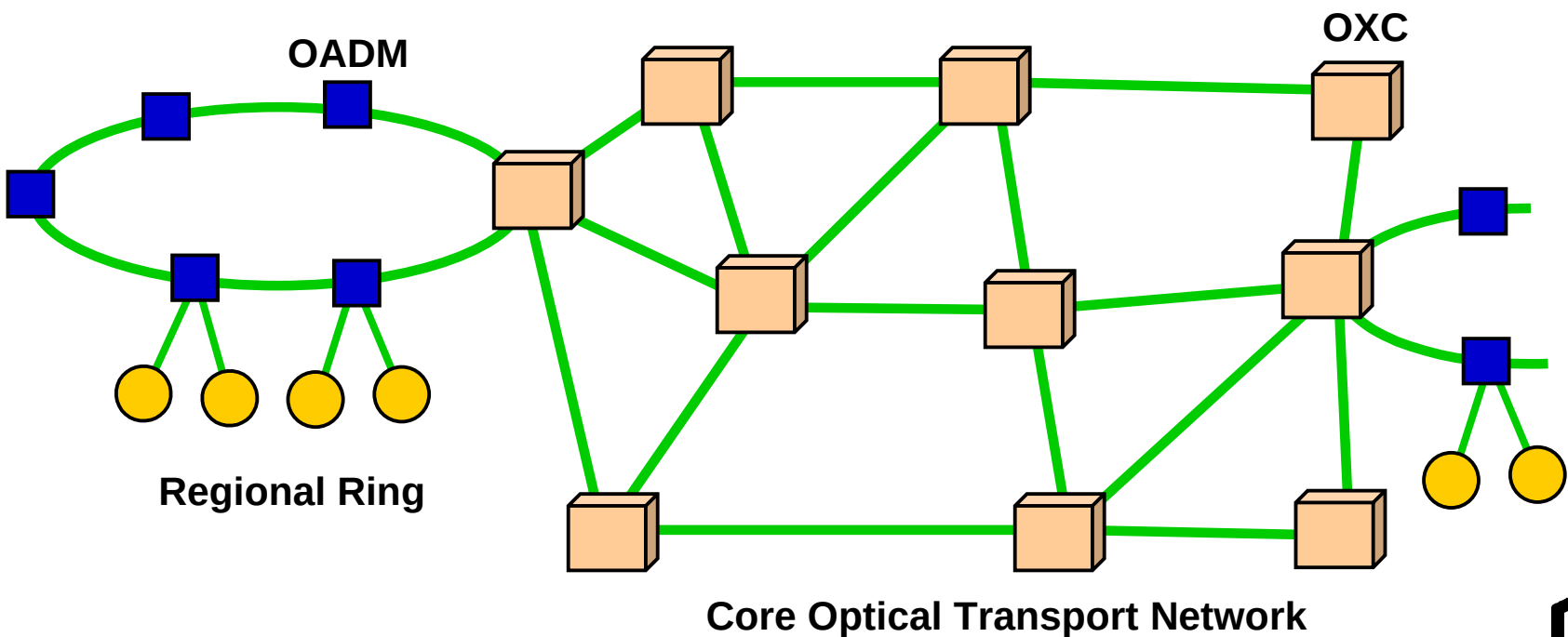
Ideal Sensor Networks for DOD Platforms



- Mixed RF/digital/analog signals
- Distributed sensors in all locations
- Connectivity (more than point-to-point)
- High survivability, fault tolerant
- Dynamic reconfigurable, wide instantaneous bandwidth

Telecom Optical Transport Networking

- **WDM is quickly evolving from point-to-point capacity expansion to scalable and robust optical transport networking (OTN)**
- **Catering to an expanding variety of client signals with equally varied service requirement**

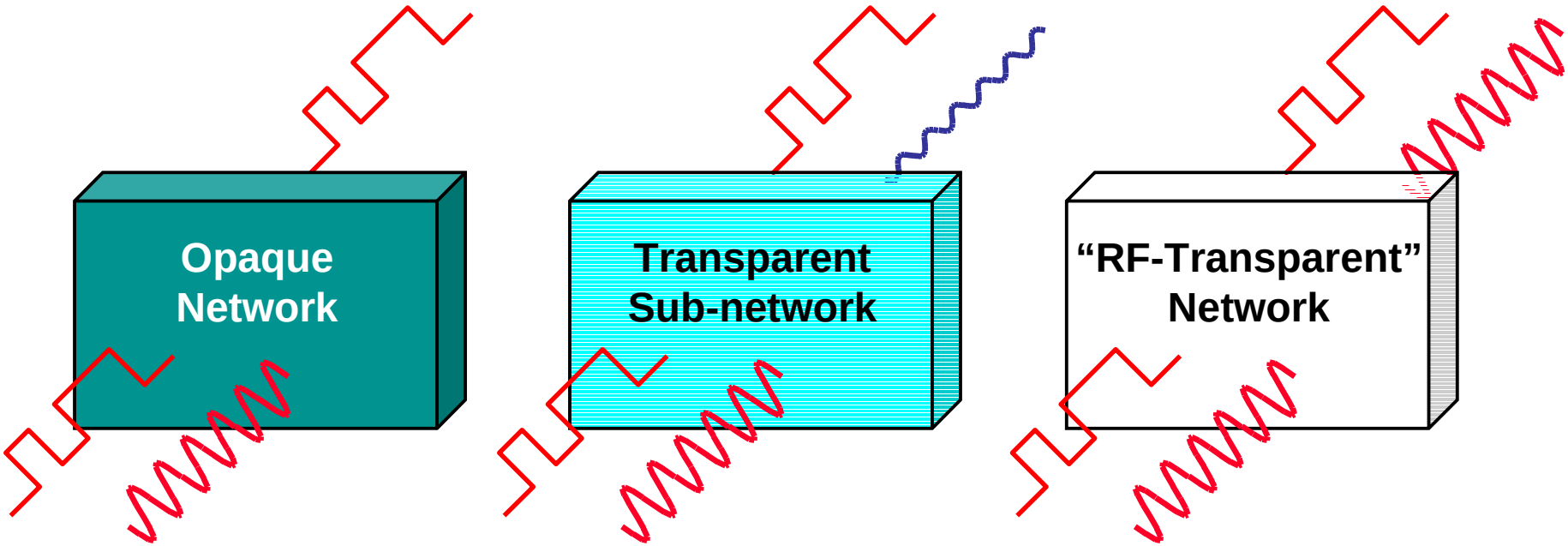


The Issue of Optical Transparency

- Early visions of "All-Optical" Transport Networking
  - Any signal (digital or analog)
  - Anywhere
  - Anytime
- "Idealized" vision tempered by practical constraints – analog network engineering → "Opaque networks"
  - "Optoelectronics" (usually with 3R) required to mitigate analog noise accumulation and maintain the network
- Practical vision of OTN
  - Optically transparent sub-networks (islands) bounded by feature-enhanced optoelectronics
  - Size and capability of the optically transparent sub-network grows as technology and standards matures

Adapted from: P. Bonenfant, "Optical Networking Standards," OFC 2000 Tutorial

Granularity of "Transparency"

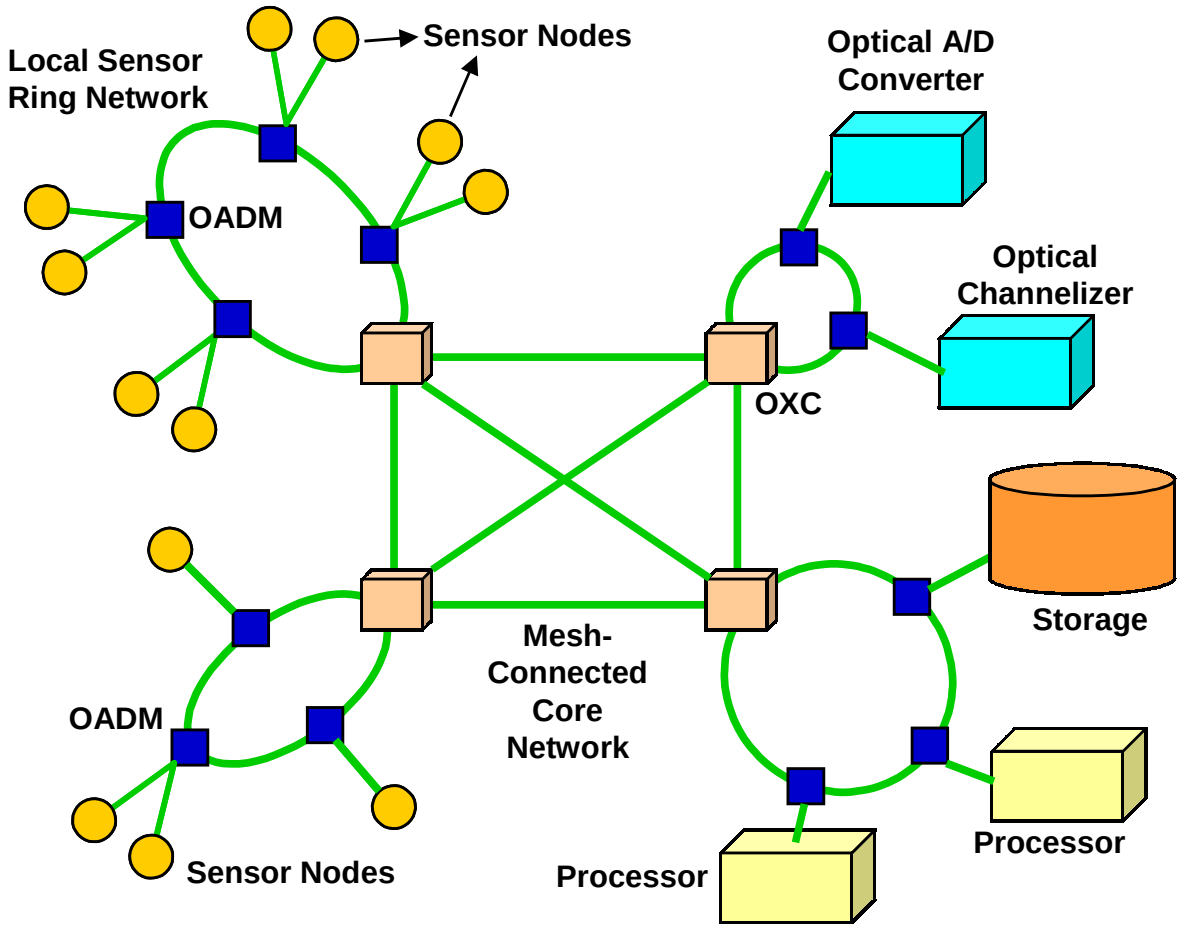


- Multi-vendor interoperability
- No cumulative impairments (noise, nonliearity)

- Provisioning and restoration at wavelength level
- RF signal integrity not guaranteed

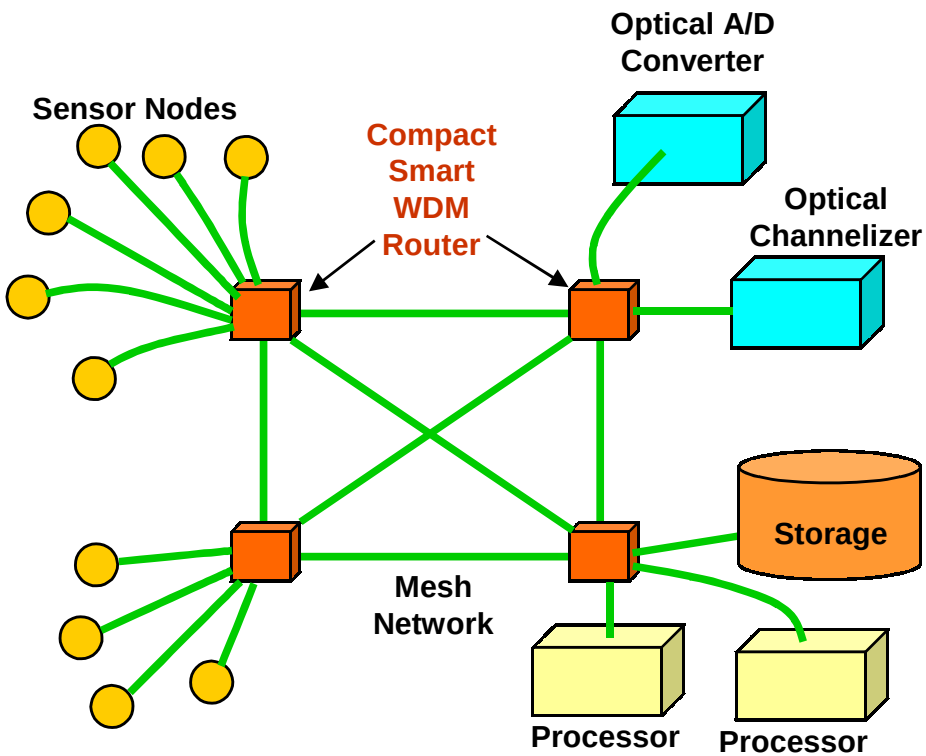
- Support mixed RF/digital signals
- Need "RF-compliant" WDM components

WDM Integrated Sensor Network



- Highly survivable
  - Built-in protection and restoration
- Dynamically reconfigurable
- Provisioning at wavelength level (Bandwidth on demand)
- Supper large number of nodes
- "Future-proof"
  - Add more sensors
  - Add optical front-end preprocessors
  - Increase RF frequency
- Pay as you grow
  - Add more wavelengths when needed

OXC for WDM Sensor Network



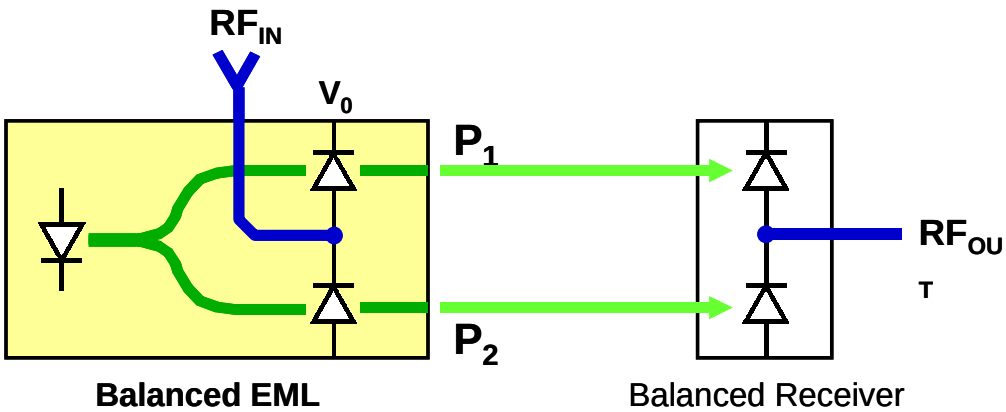
- Need much more compact OXC
  - Telecom OXC too big in size, weight, power, and capacity
- What can we do without?
  - Probably don't need wavelength conversion (?)
  - → Use wavelength-selective cross connect (WSXC)
- Combine WSXC and OADM
  - Smart WDM Router

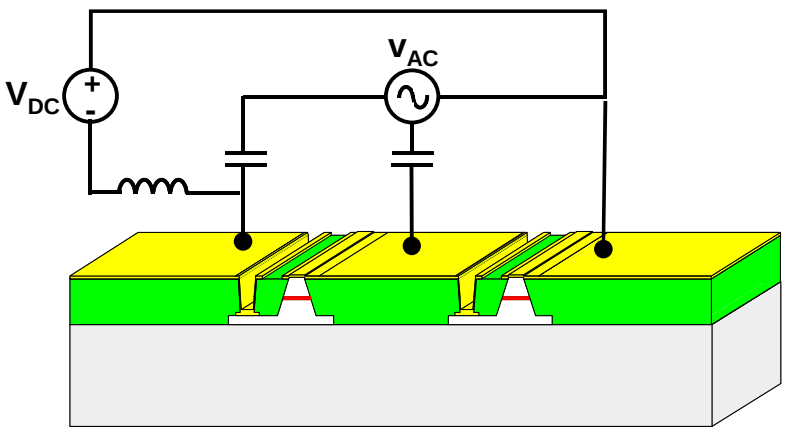
RF-Compliant Components

- **WDM components with < -40 dB optical isolation**
- **Flat passband response**
- **Many RF-compliant optoelectronic components are being developed by RFLICS**

- **Balanced EA modulator with high linearity and low noise**

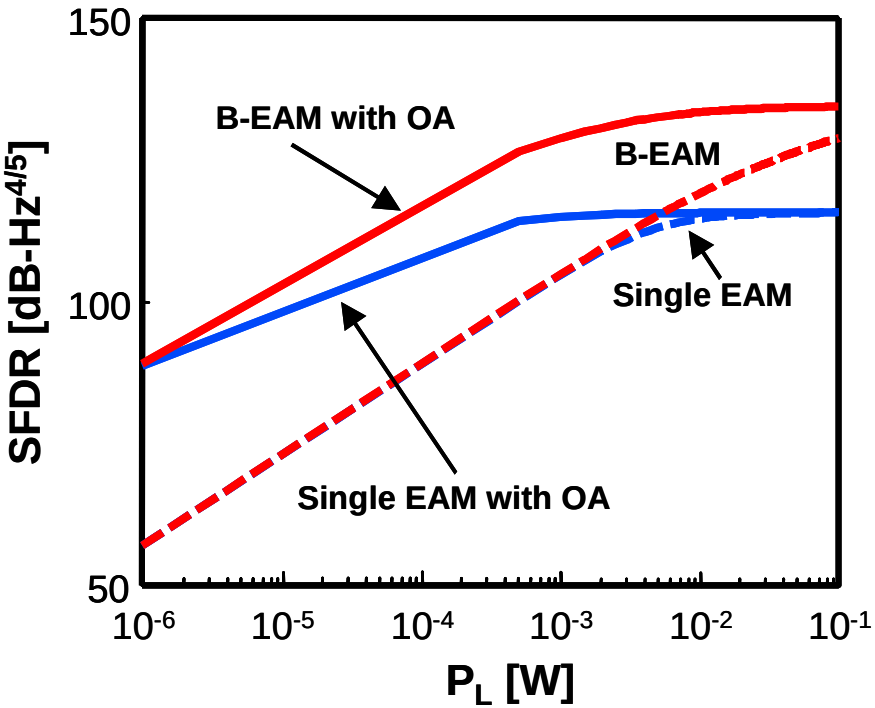
Balanced EA Modulator (BEAM) for "RF-Transparent" WDM Networks

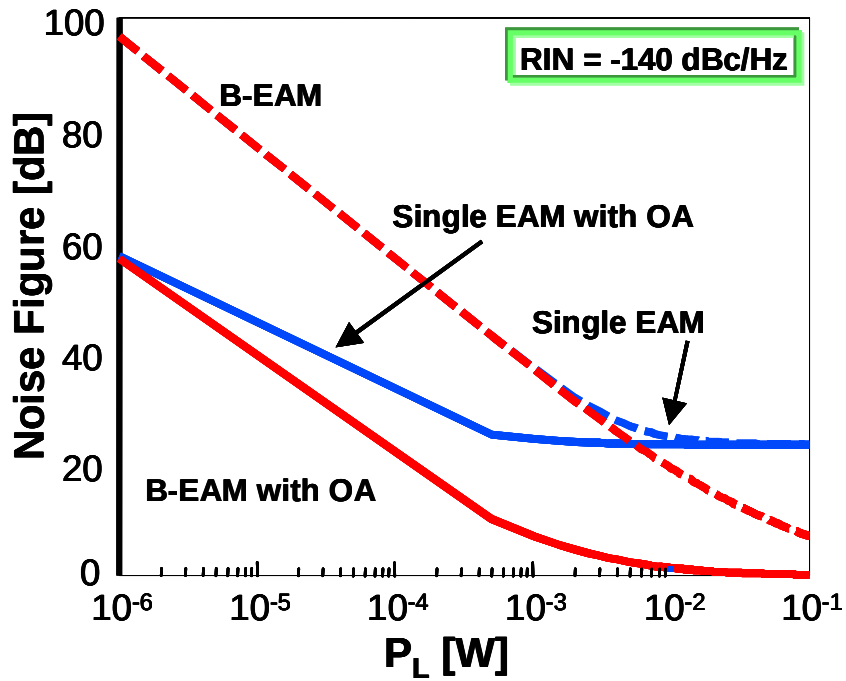




- Complementary output at all bias voltages
- BEAM balanced link:
  - All even order distortions cancelled
  - 3rd order intermod nulled
  - RIN cancelled
  - Common ASE of SOA suppressed
- High fidelity link achieved with telecom-grade lasers and modulators
- Ideal for mixed mode (digital + RF) WDM networks

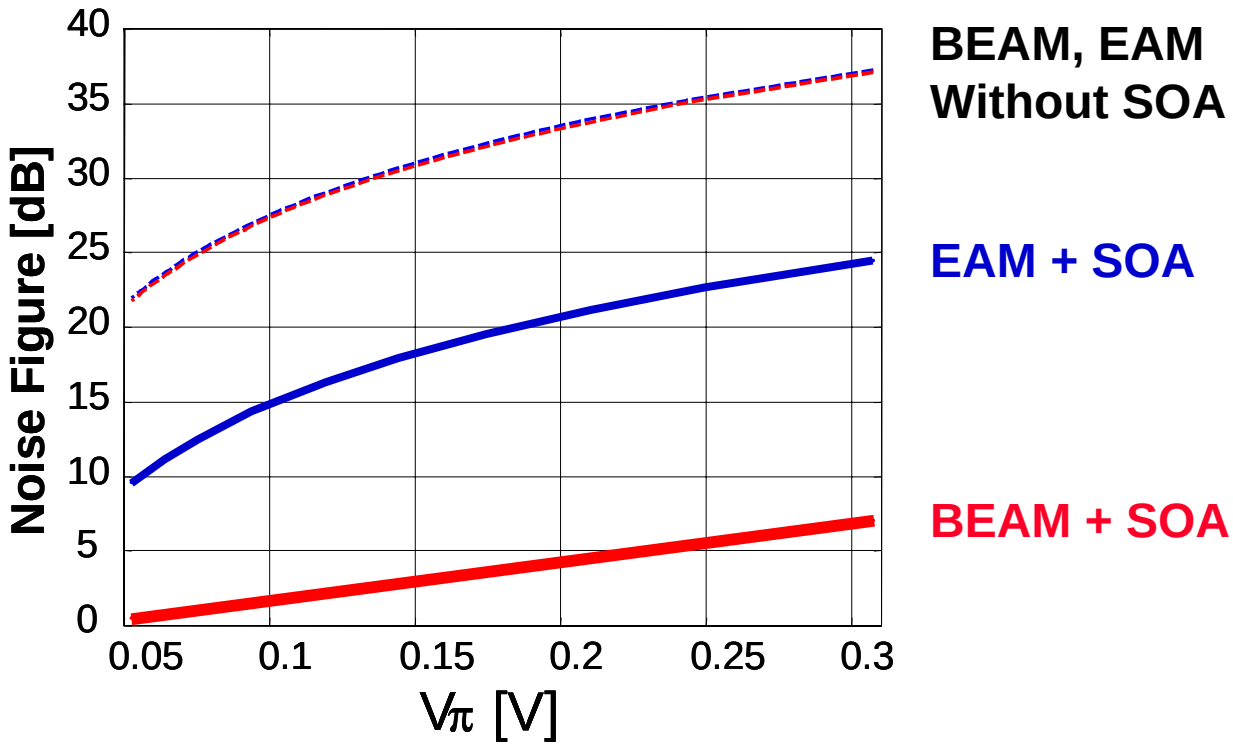
Calculated Spurious-Free Dynamic Range and Noise Figure of BEAM





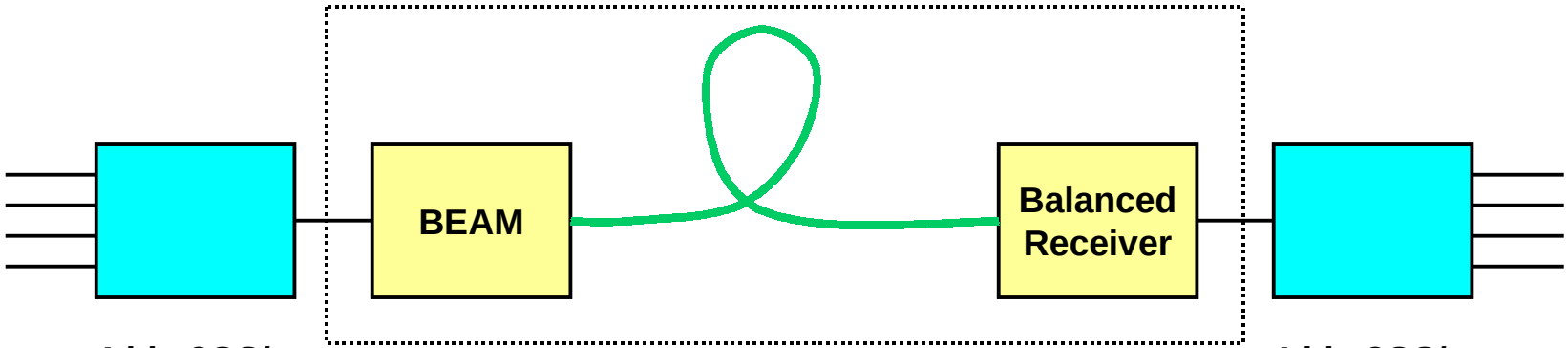
High SFDR and low NF can be achieved at moderate laser power and RIN

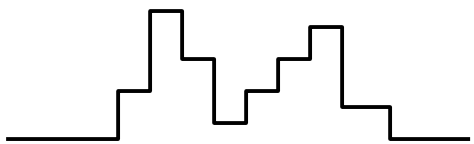
Comparison of BEAM and EAM

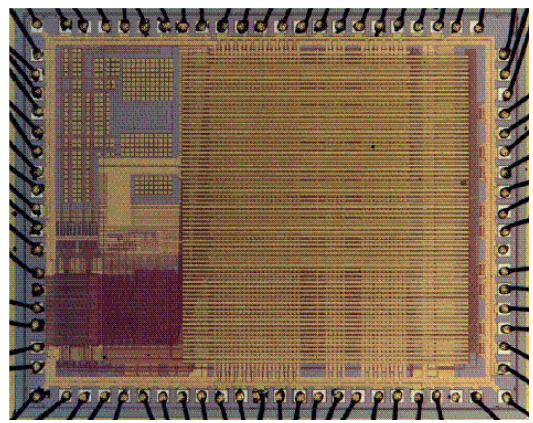


- **Noise Figure of BEAM is lower than EAM with 5x lower Vπ**

Ultra-High Speed Link using CMOS Multi-Level Tx/Rx Chips



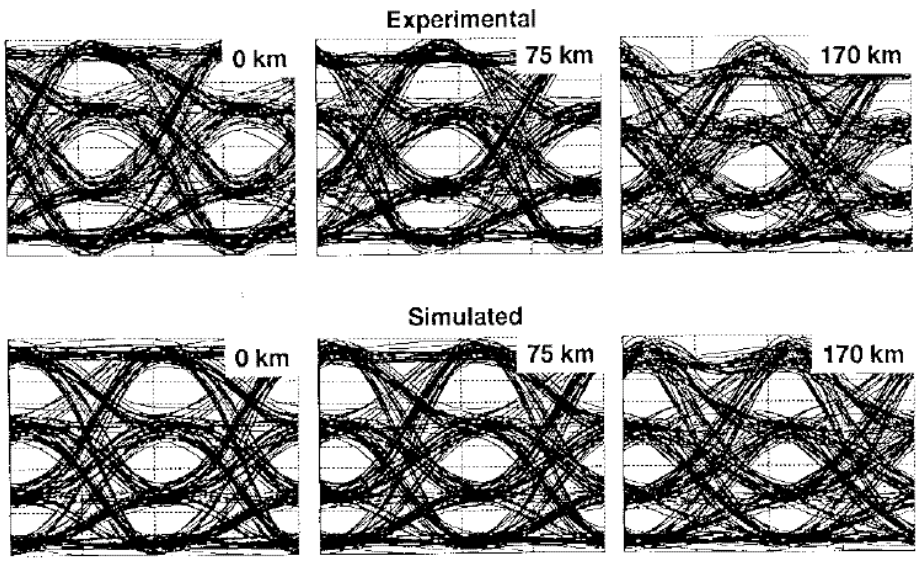




0.25 μm CMOS
Prof. Ken Yang (UCLA)

- 30 Gbps transmission by combining linear link with high speed CMOS DAC/ADC
- High spectral efficiency (>> 1 bit/Hz)
- Prof. Ken Yang (UCLA), leader in high speed CMOS Tx/Rx design

Multi-Level Signaling Digital Transmission



- **M-ary signaling**
  - **Reduced bandwidth (bandwidth ~ symbol rate)**
  - **Increased spectral efficiency (>> 1 b/sec/Hz)**
  - **Resistant to dispersion**
  - **40 Gbit/s over 35 km standard single mode fiber demonstrated by Alcatel**
- **For large M**
  - **Need network with large SFDM**
  - **Need more optical power**

- Walklin, S.; Conradi, J. “Multilevel signaling for increasing the reach of 10 Gb/s lightwave systems. IEEE Journal of Lightwave Technology, vol.17, p.2235-48, 1999.
- Wedding, et al. (Alcatel), “40 Gbit/s quaternary dispersion supported transmission over 31 km standard single mode fiber without optical dispersion compensation,” ECOC ’98, p.523.

SUMMARY

- **“RF-transparent” WDM network for sensor networks for military platforms**
- **Compact Smart WDM Router**
- **Balanced electro-absorption modulator (BEAM) for mixed RF/digital signals**
- **Multi-level signaling for possible 40 Gbit/sec WDM in CMOS**